

Induced Voltage on Objects under Six-Phase Transmission Line

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Abstract— This paper presents results of an experimental investigation on voltage induced on objects under a six-phase transmission line due to line switching incidences. In this work, the voltage induced on a vertical receiver and a pipeline due to line energization and de-energization in a six-phase power transmission line system is reported. The research was carried out using a six-phase transmission line mock-up system with ratio of 5/132 kV. The results showed that the induced voltage on the objects is less than 4 kV. In addition the high induced voltage experienced by the vertical receiver was from the left side of the phase composition while the pipeline experienced higher induced voltage from the right side phase composition.

Keywords- six-phase system; transmission line; switching; induced voltage; surge

I. INTRODUCTION

Day by day, the demand of electric energy supply continues to increase. As a result of this, large amount of electrical energy must be transferred from power plants to consumers via power transmission and distribution lines [1,2,3]. Transmission line connects the neighbouring utilities within regions during normal conditions and emergencies. Generally, the grid system is applied to ensure adequate and stable supply of electrical energy to customers [4,5,6] since the interruption of electricity supply can result in huge losses.

In many cases, the utilities companies will be faced with the problem of limited capacity of existing transmission line when they need to deliver larger electrical energy to load centres.

To increase the amount of the power transmitted through the existing transmission lines, there are several alternatives that can be taken into consideration such as increasing the line voltage, increasing the current voltage, adding series and shunt compensation or applying six-phase transmission line system [7].

Converting from three-phase transmission line system to six-phase transmission line will increase the capacity, about 73%, of the power that can be delivered [7]. But when the

power of a transmission line is increased, the induced voltage on objects around it increases as well [8].

This paper presents the results of observations made on two objects placed under a six-phase transmission line at the time of opening and closing the circuit connection, which led to the emergence of switching surges. Switching surges that occur in power systems are as a result of instantaneous changes in the electrical configuration of the system.

II. METHODOLOGY

In this work, to observe the effects of switching incidences a mock-up six-phase transmission line system developed in Institute of High Voltage and High Current (IVAT) was utilised. The mock-up transmission line system has a maximum working voltage of 5 kV, which represents the 132 kV three-phase double line circuit transmission line of Tenaga Nasional Berhad (Malaysian national power company). The line is 113.1 km in length and is between Gua Musang and Kuala Krai, Kelantan, Malaysia. Fig. 1 shows the six-phase transmission line mock-up system while Fig. 2 presents the composition of the phase cables in the transmission tower. A detailed description of the six phase transmission line mock-up system is described in [9]



Figure 1. Six-phase transmission line mock-up system.

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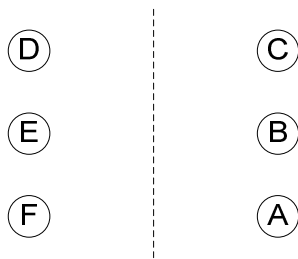


Figure 2. Six-phase transmission line cable configuration.

To investigate the induced voltage experienced by objects in the vicinity of the six phase transmission line system, a vertical receiver and a pipeline were placed under the six phase line and the magnitude of the induced voltage from the transmission line induced on them was observed. The pipeline was placed perpendicular to the transmission line. The vertical receiver unit was inspired from a pedestrian High Frequency (HF) Mobile Antenna [10,11].

The flow chart of the experimental procedure for measuring the switching surges on the transmission line system (TLS) and the magnitude of the voltage induced on the Vertical Receiver (VR) and Pipeline (PL) is shown in Fig. 3. The transmission line system voltage is in kilovolts, a HV probe of ratio 1:1000 V was used to fraction the voltage to the allowable voltage limit of the analogue to digital converter (ADC) unit. Picoscope as an ADC was used to interface the computer and probe. The Picoscope has two channels (A and B) and a USB port for communication with a computer. In the computer, the waveform and magnitude of the switching surges and induced voltages on the objects were displayed and saved.

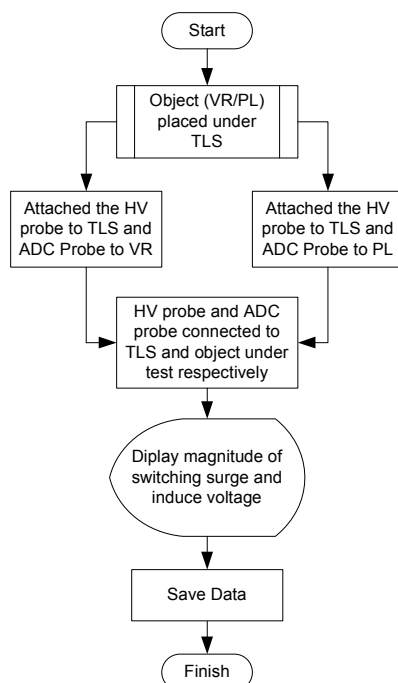


Figure 3. Flow chart of experimental procedure.

As shown in Fig. 3, the data collection was carried out in two parts. This is due to the limited capacity of the ADC which has only two channels. The first experiment was carried out with VR placed under the TLS. While the second experiment was carried out with PL placed under the TLS.

Transmission line system is equipped with terminals and switches that are used to observe the switching surge that appears on the transmission line. Each phase has a terminal as shown in Fig. 4. For measurement the terminal was connected to channel A of Picoscope through a HV probe, while for channel B was used to observe the induced voltage on objects placed under the line which in this case the vertical receiver and the pipeline. Fig. 5 shows the pictures of the pipeline and vertical receiver. To simulate various types of switching using the mock-up system, the procedures in Table 1 were followed. All experiments were conducted with load connected. Data were taken three times and then averaged. The data taken were the peak-to-peak voltage and switching magnitude.

TABLE I. OBSERVATION PROCEDURE

Switching Type	Procedure
Single-phase	The phase under test was energised/de-energised by opening/closing its switch while all other phases remain closed.
Three-phase	The three phases under test were energised/de-energised by opening/closing a switch common to the three phases while rest of the phases remain closed
Six-phase	All six phases were energised/de-energised using a switch common to all the phases.
Load	The switch connecting the six phase line and the load was energised/de-energised



Figure 4. Transmission line system terminals.



Figure 5. The objects under six-phase transmission lines (a) Vertical receiver and (b) Pipeline.

III. RESULTS AND DISCUSSION

Fig. 6 and 7 show the results of the induced voltage on the vertical receiver and pipeline respectively due to the switching that occurs in the transmission line. In the figures, the x axis represents the switching conditions while y axis represents the magnitude of the induced voltage.

It can be seen from Fig. 6 that the induced voltage on the vertical receiver for all switching conditions were below 4 kV except for the two switching conditions of *Phase F* (six-phase-off and load-off) and *Phase D* (load off). The induced voltage in *Phase F* switching conditions were 6.5 kV and 8.0 kV while *Phase D* was slightly above 4.0 kV.

Referring to Fig. 7, it can similarly be seen that the most of the induced voltage on the pipeline under the switching conditions were below 4.0 kV except for *Phases A* and *B*. *Phase B* experienced induced voltage of 8.0 kV and 16.0 kV under switching conditions of load off and six phase off while *Phase A* experienced an induced voltage of 8.0 kV in the load off condition. The maximum induced voltage experienced by the pipeline is approximately twice the maximum induced voltage experienced by the vertical receiver in load off switching condition. But both objects experienced induced voltages of less than 4.0 kV in most of the switching conditions.

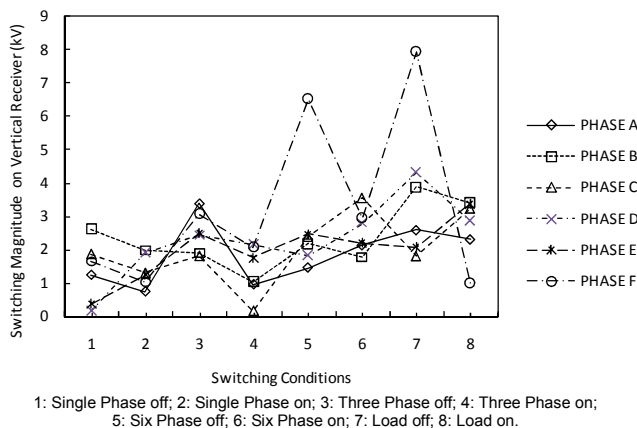


Figure 6. Induced voltage on the vertical receiver.

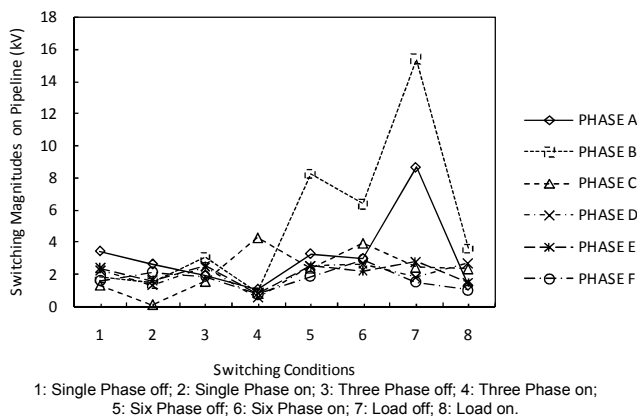


Figure 7. Induced voltage on the pipeline.

From the above results, it can be seen that the high induced voltages (above 4.0 kV) experienced by the vertical receiver were mainly from the left side phase composition (D, E, and F), while the pipeline experienced high induced voltages from right side phase composition (C, B, and A) of the six phase transmission line.

IV. CONCLUSION

This paper has described the induced voltage experienced by objects under a six-phase transmission line system due to switching surges. From this work it was observed that the induced voltage were mostly below 4.0 kV.

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